

Source-apportionment for mercury deposition: Where does the *mercury* in *mercury deposition* come from?

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**For many (but not all) aquatic ecosystems,
much of the loading comes directly or indirectly
through the atmospheric pathway...**

For the atmospheric pathway:

- ☐ How much of the mercury in atmospheric mercury deposition comes from local, regional, national, continental, and global sources?**
- ☐ How important are different source types?**

1. The impact of any given mercury emissions source on any receptor is highly variable

- ❑ extreme spatial and temporal variations**
- ❑ Think about the weather and then add all the chemistry and physics of mercury's interactions with the “weather”**

Example simulation of the atmospheric fate and transport of mercury emissions:

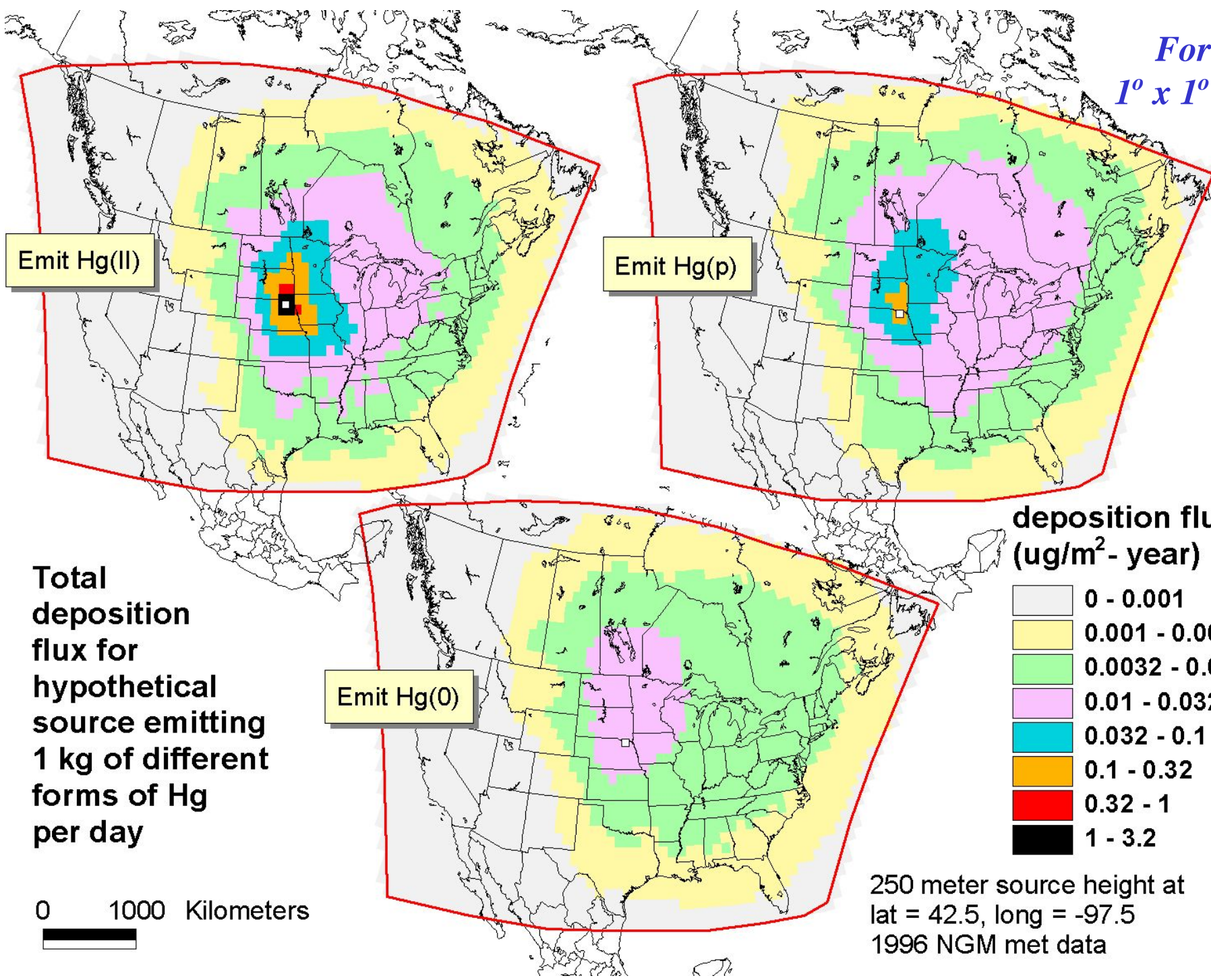
- ☐ **hypothetical 1 kg/day source of RGM**
- ☐ **source height 50 meters**
- ☐ **results tabulated on a 1° x 1° receptor grid**
- ☐ **daily results for one month (May 1996)**

See
27_USGS_Source__Apportionment_Movie.ppt
or
27_USGS_Source__Apportionment_Movie.pdf

2. The impact of any given mercury emissions source on any receptor is highly dependent on the “type” of mercury emitted

- ☐ **Elemental mercury - Hg^0 - is not readily dry or wet deposited, and its conversion to ionic Hg or $\text{Hg}(\text{p})$ is relatively slow**
- ☐ **Particulate mercury – $\text{Hg}(\text{p})$ - is moderately susceptible to dry and wet deposition**
- ☐ **Ionic mercury – also called Reactive Gaseous Mercury or RGM – is very easily dry and wet deposited**
- ☐ ***Conversion of RGM to Hg^0 in plumes?***

*For a
1° x 1° grid*



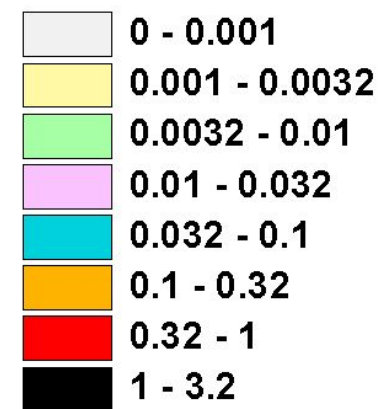
Emit Hg(II)

Emit Hg(p)

Emit Hg(0)

**Total
deposition
flux for
hypothetical
source emitting
1 kg of different
forms of Hg
per day**

**deposition flux
(ug/m²- year)**

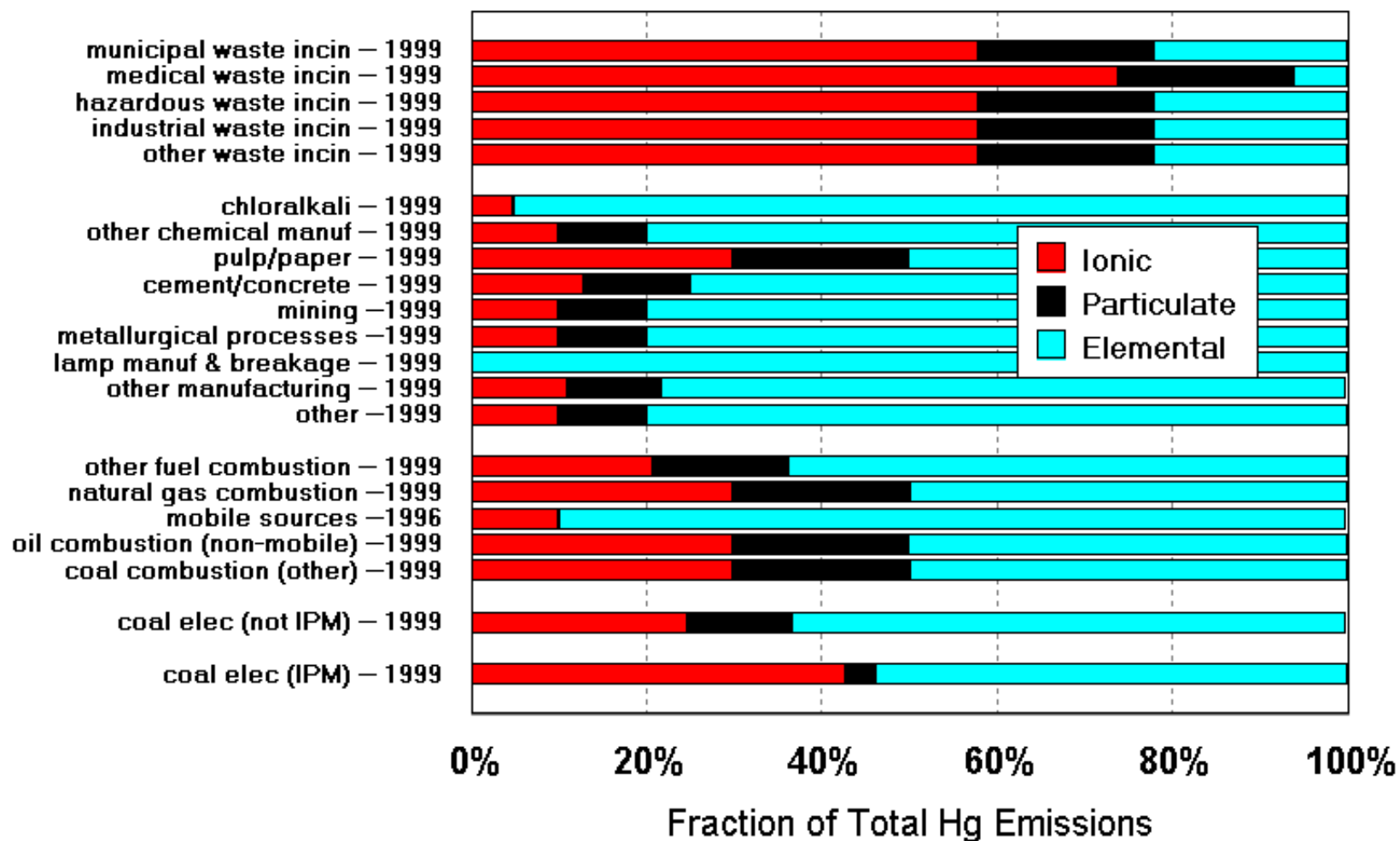


0 1000 Kilometers

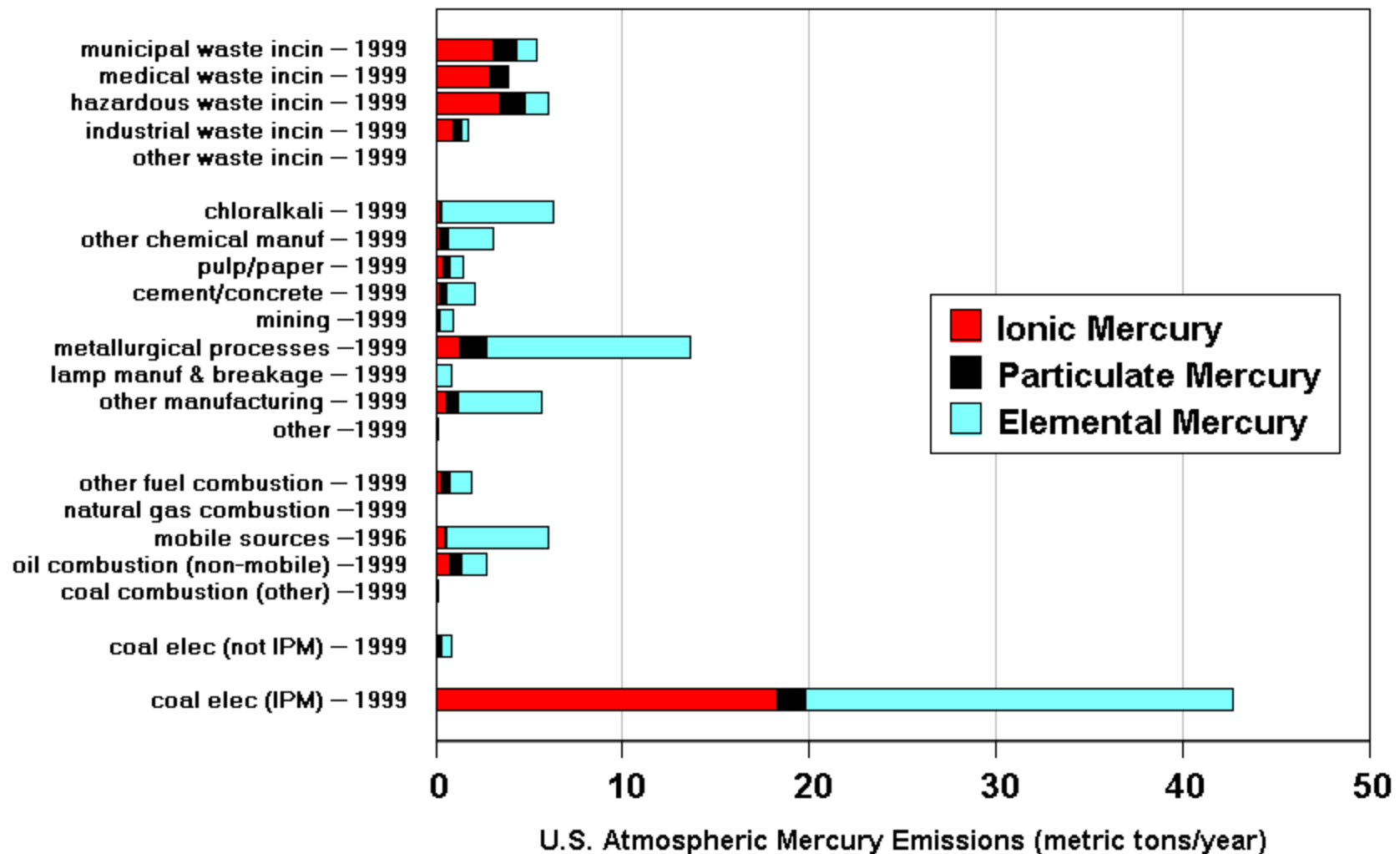
250 meter source height at
lat = 42.5, long = -97.5
1996 NGM met data

Estimated Speciation Profile for 1999 U.S. Atmospheric Anthropogenic Mercury Emissions

Very uncertain for most sources



Estimated 1999 U.S. Atmospheric Anthropogenic Mercury Emissions



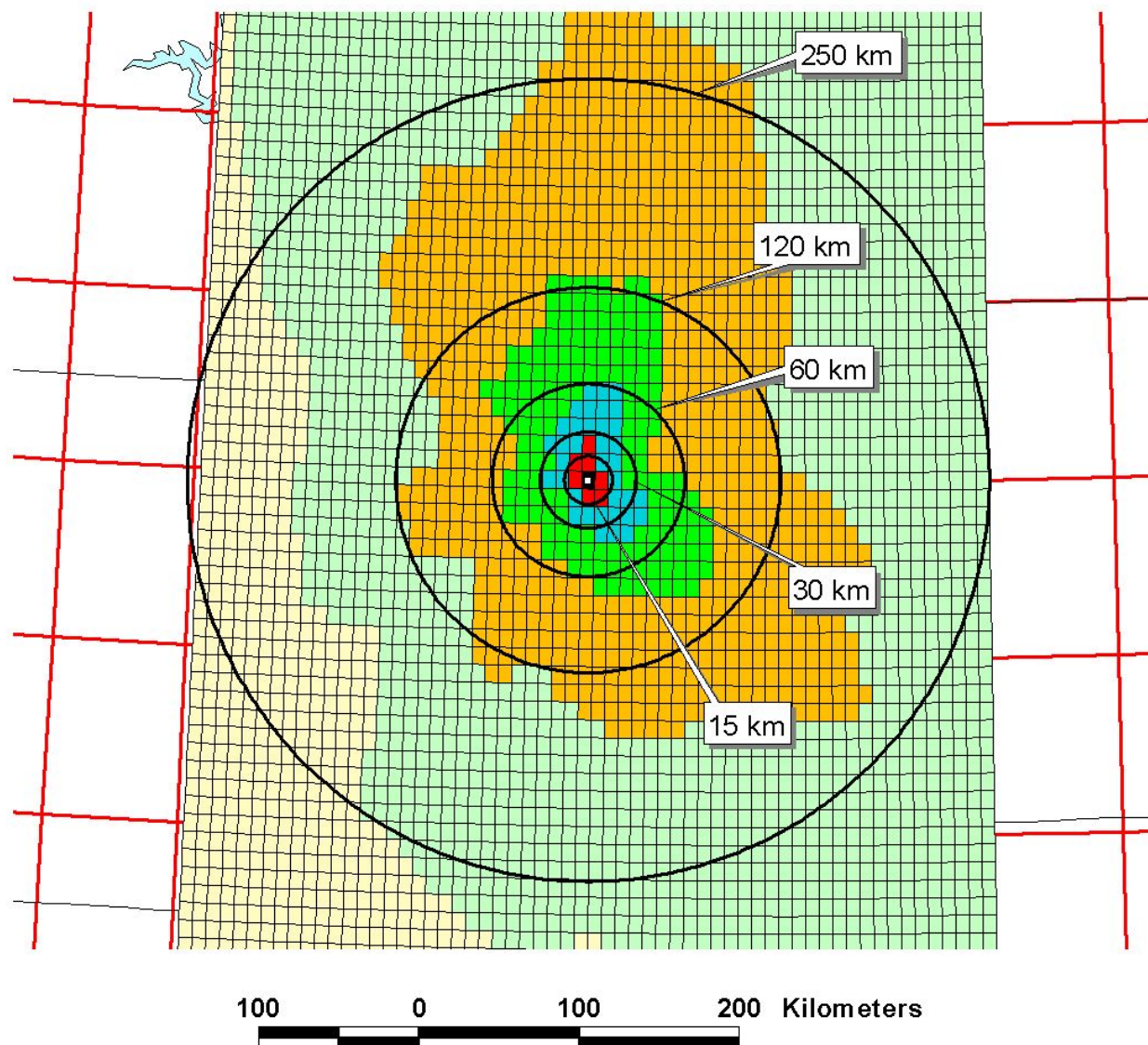
- ❑ Each type of source has a very different emissions speciation profile**
- ❑ Even within a given source type, there can be big differences – depending on process type, fuels and raw materials, pollution control equipment, etc.**

3. There can be large local and regional impacts from any given source

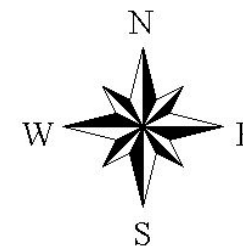
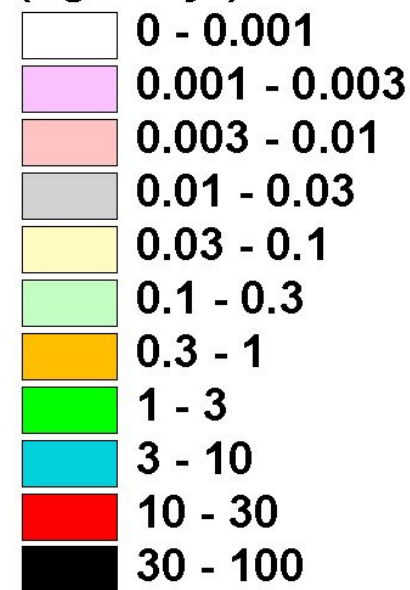
- ❑ same hypothetical 1 kg/day source of RGM**
- ❑ source height 250 meters**
- ❑ results tabulated on a $0.1^\circ \times 0.1^\circ$ receptor grid**
- ❑ overall results for an entire year (1996)**

**total (wet + dry) annual deposition flux for
source emitting 1 kg/day of Hg(II)**

For a $0.1^\circ \times 0.1^\circ$ grid



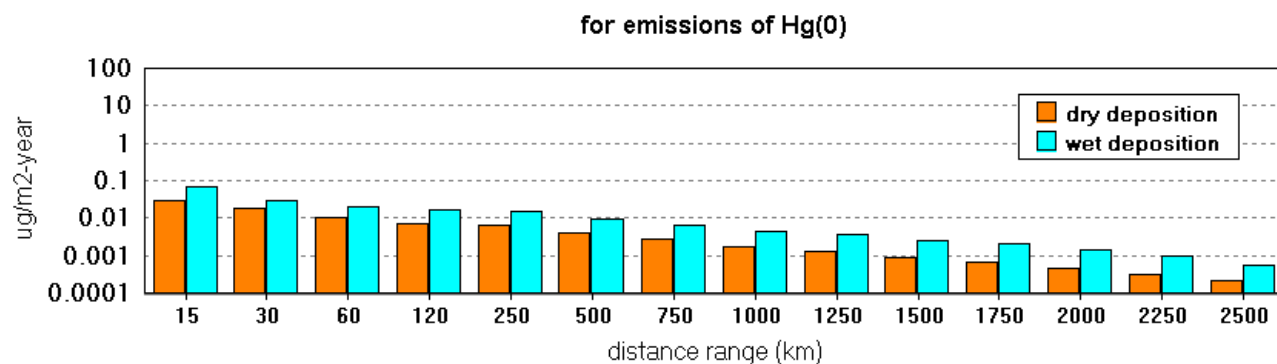
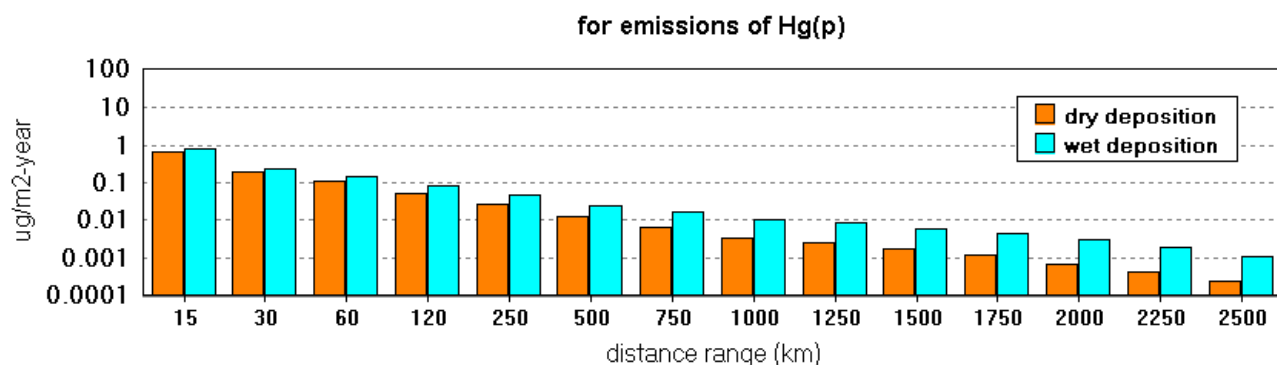
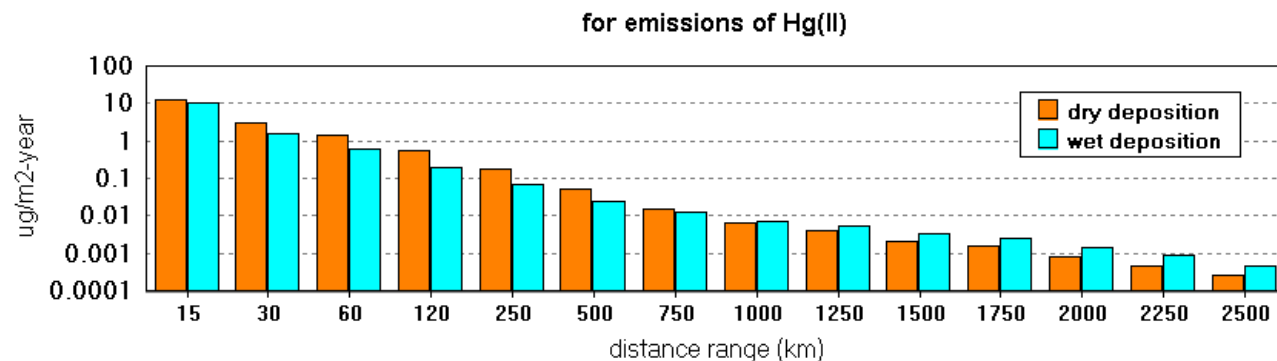
**deposition flux
(ug/m2-yr)**



250 meter source height at
lat = 42.5, long = -97.5
1996 NGM met data

Deposition Flux (ug/m²-year) deposited within different distance ranges away from a hypothetical source

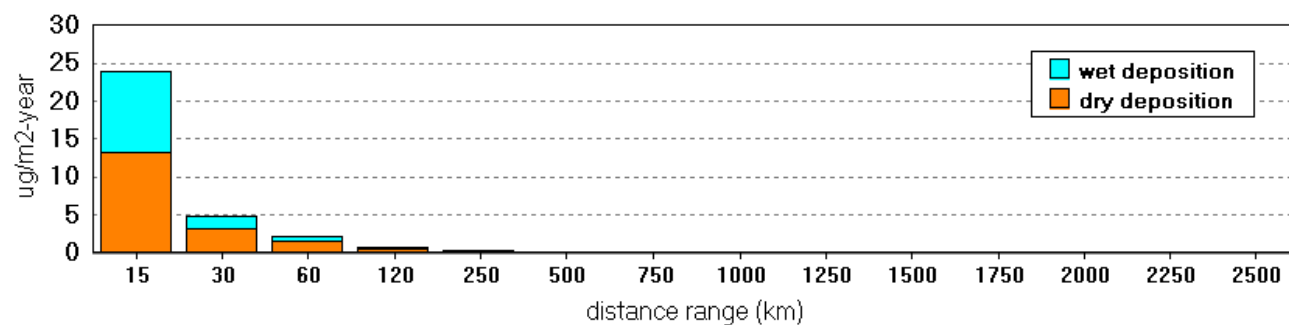
[250 meter source height. Source at latitude 42.5, longitude -97.5. Results for entire year 1996 using NGM met data.]



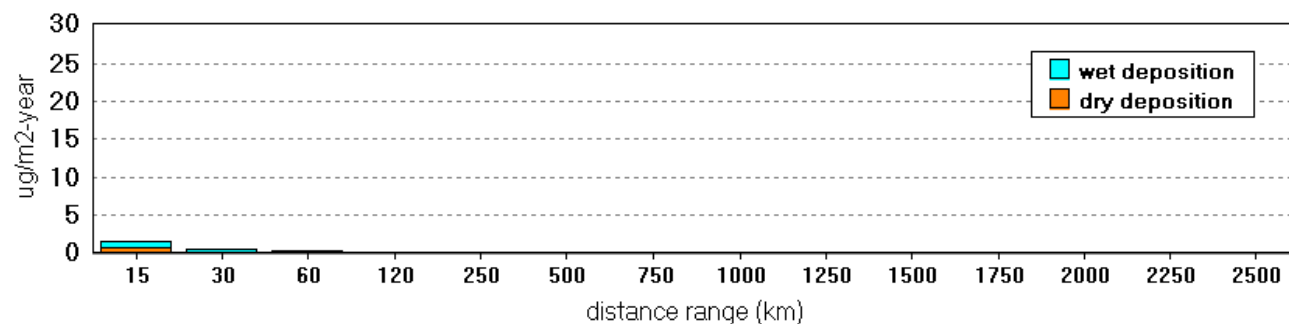
Deposition Flux (ug/m2-year) deposited within different distance ranges away from a hypothetical source

[250 meter source height. Source at latitude 42.5, longitude -97.5. Results for entire year 1996 using NGM met data.]

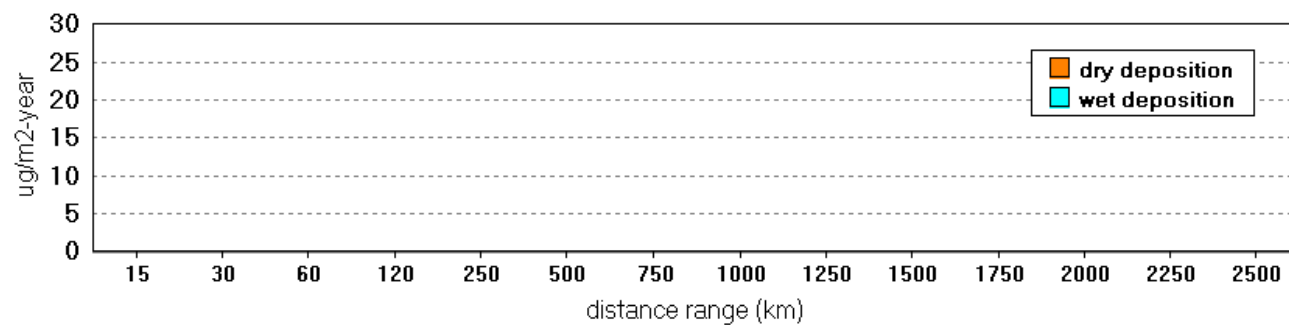
for emissions of Hg(II)



for emissions of Hg(p)



for emissions of Hg(0)

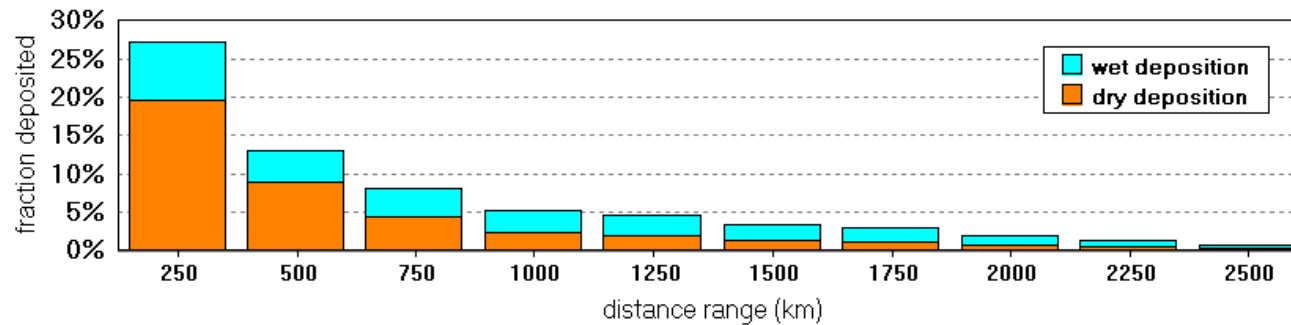


4. At the same time, medium to long range transport can't be ignored

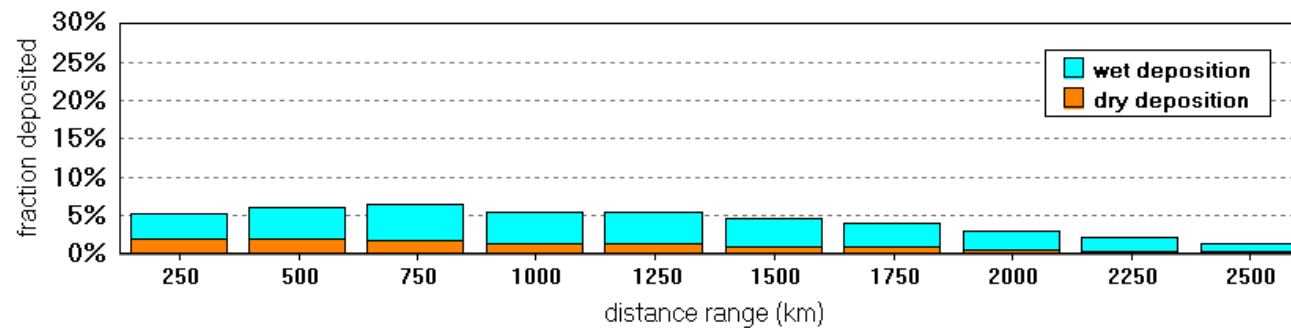
Fraction of emissions deposited within different distance ranges away from a hypothetical source

[250 meter source height. Source at latitude 42.5, longitude -97.5. Results for entire year 1996 using NGM met data.]

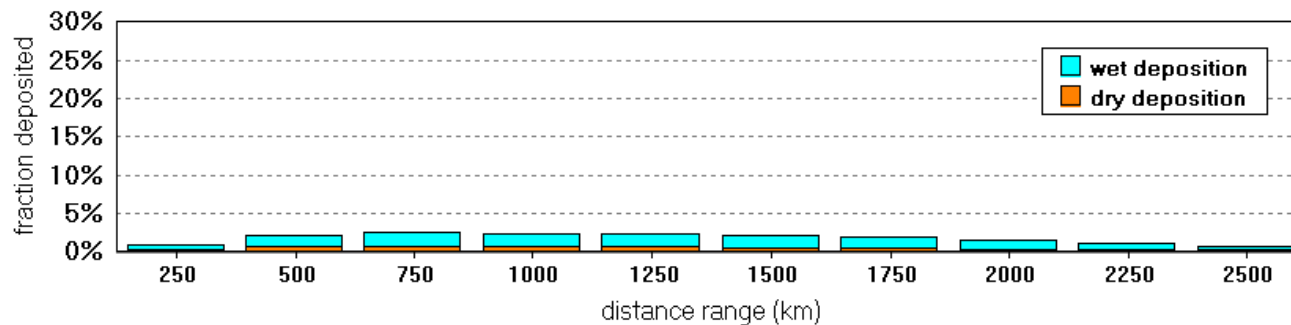
for emissions of Hg(II)



for emissions of Hg(p)



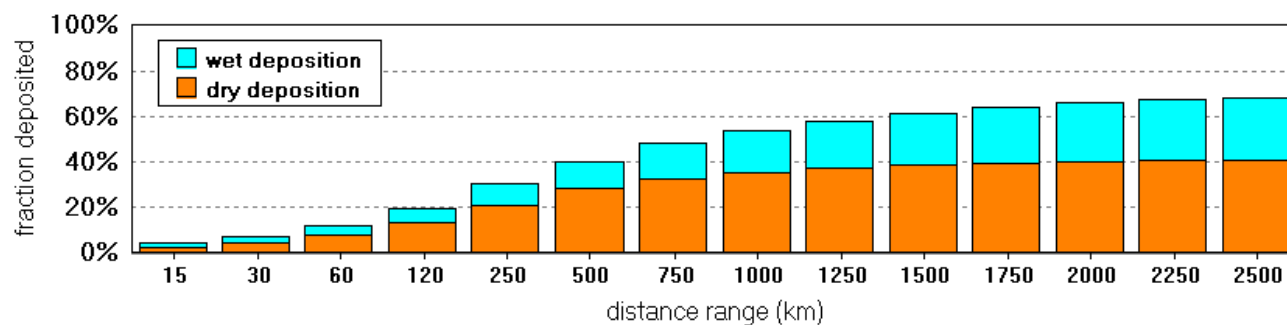
for emissions of Hg(0)



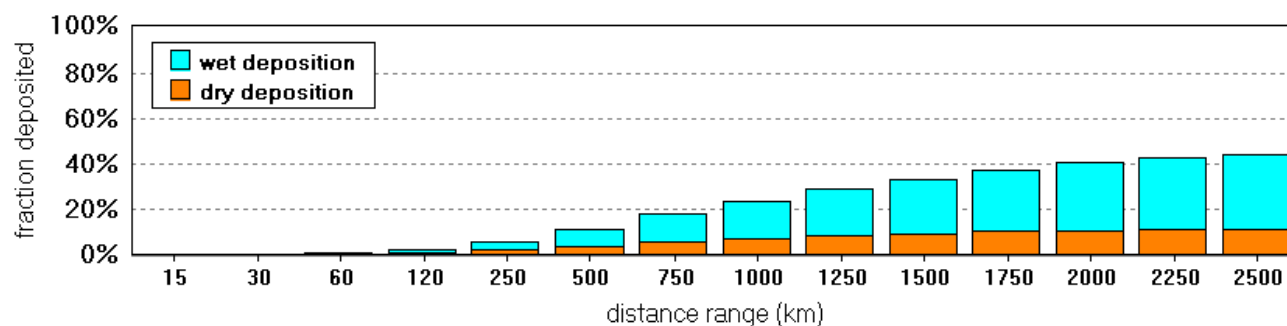
Cumulative fraction of emissions deposited within different distance ranges away from a hypothetical source

[250 meter source height. Source at latitude 42.5, longitude -97.5. Results for entire year 1996 using NGM met data.]

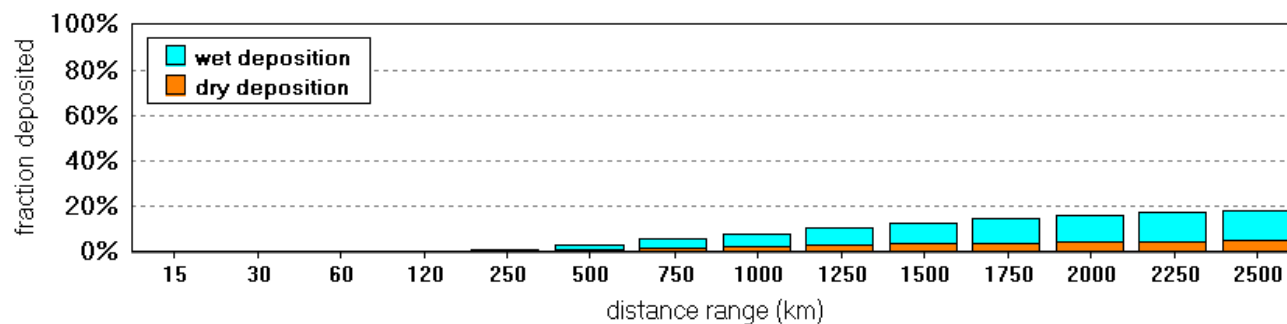
for emissions of Hg(II)



for emissions of Hg(p)



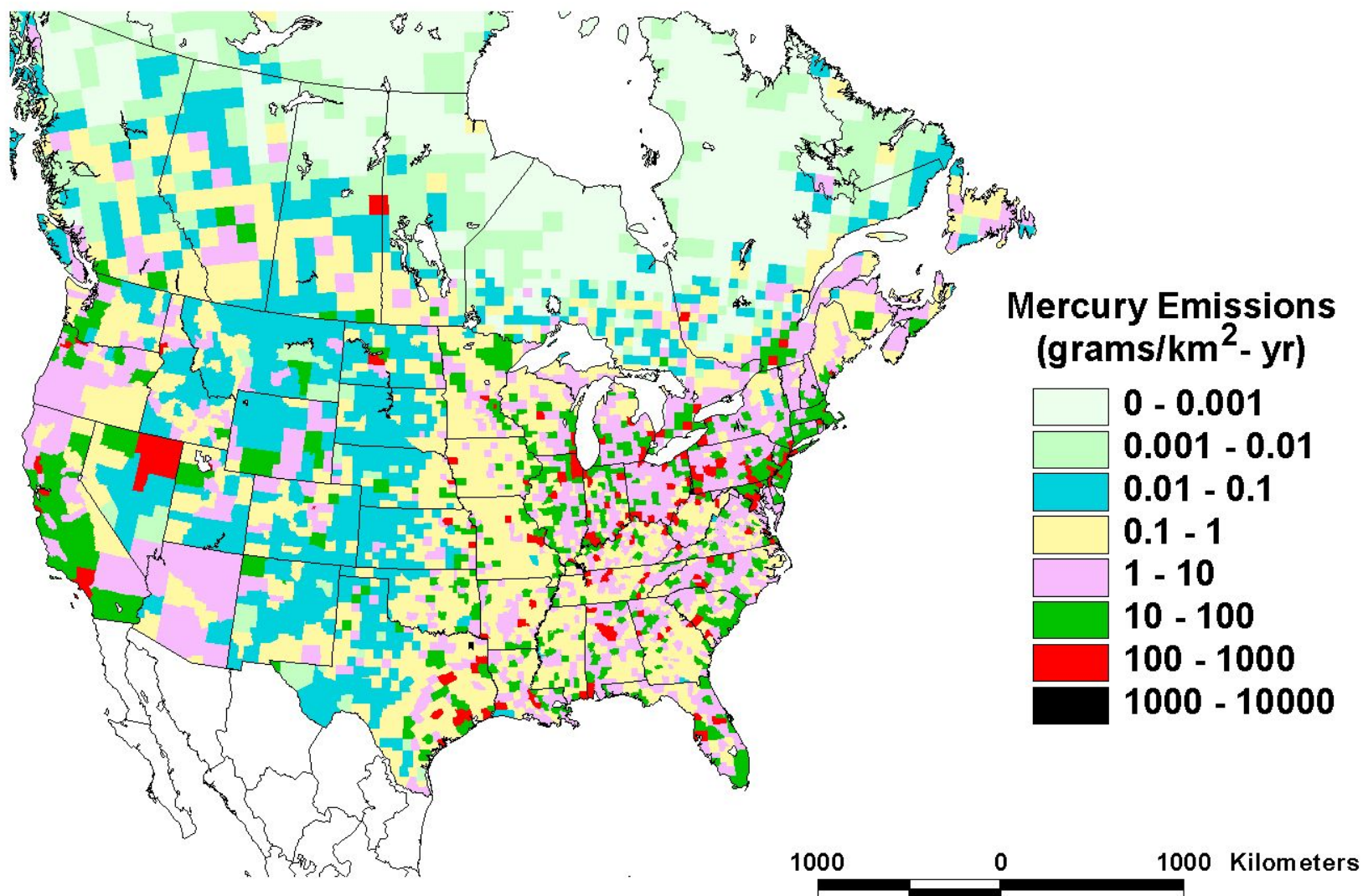
for emissions of Hg(0)



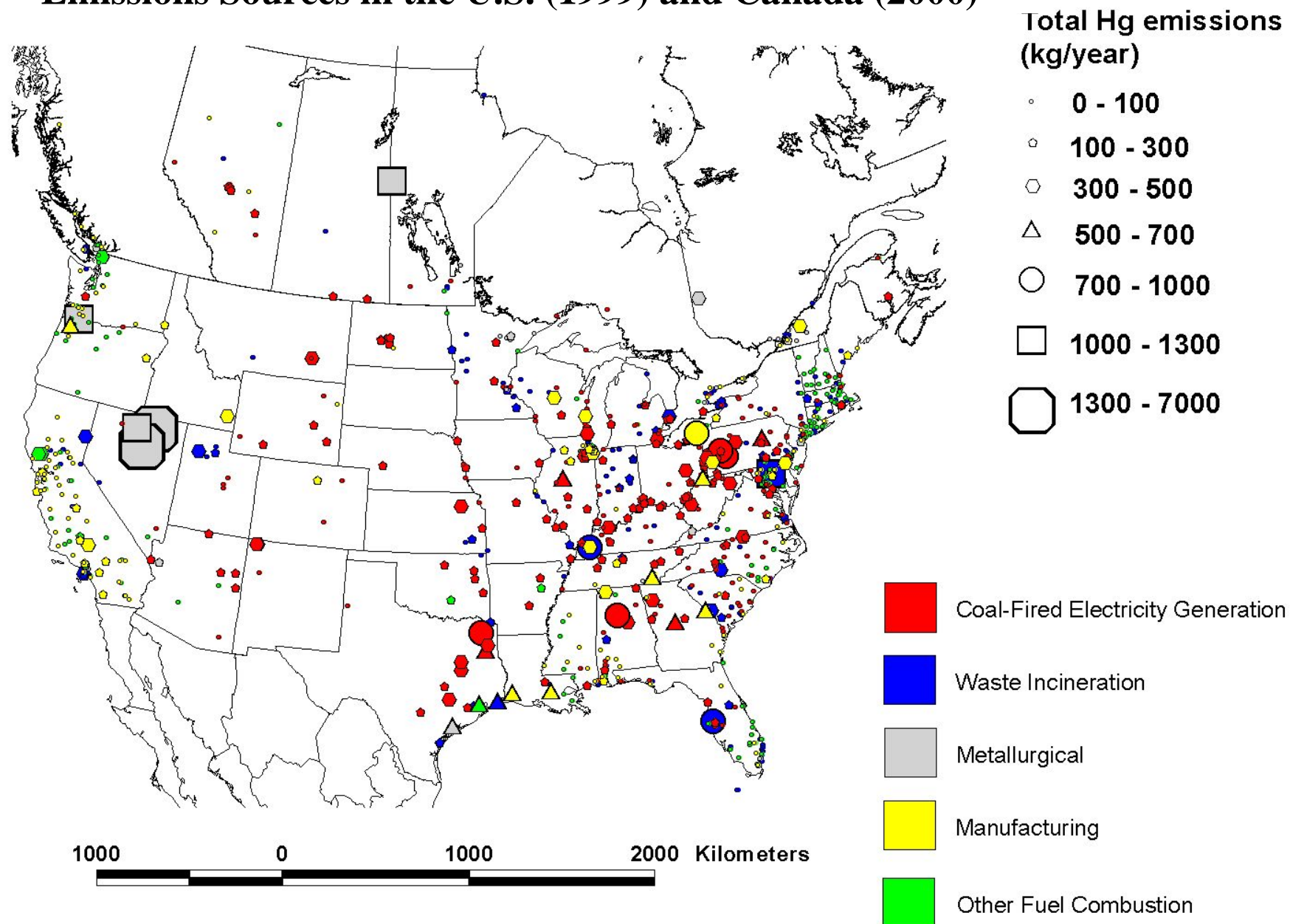
5. There are a lot of sources...

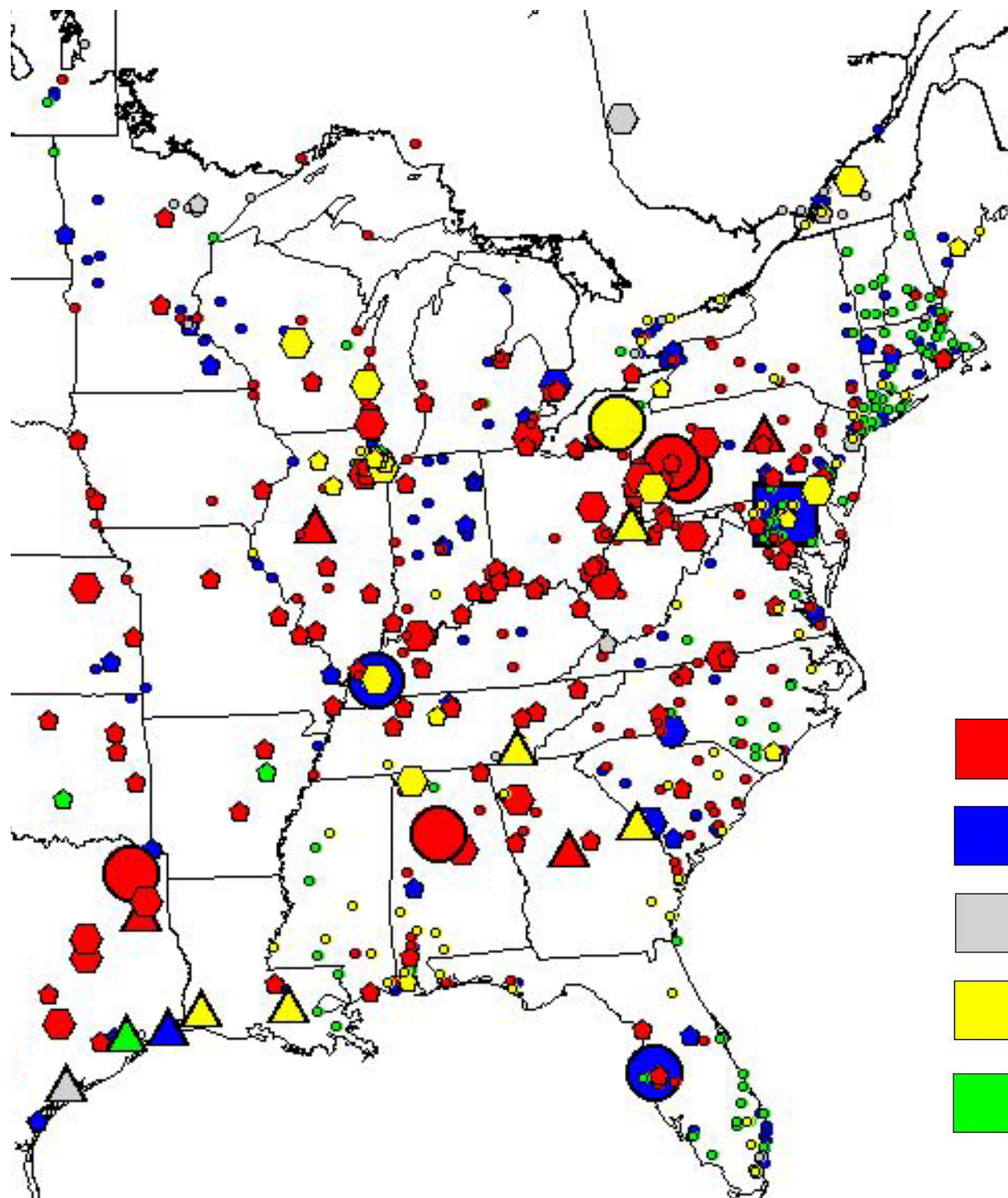
- ❑ Large spatial and temporal variations**
- ❑ Each source emits mercury forms in different proportions**
- ❑ A lot of different sources can contribute significant amounts of mercury through atmospheric deposition to any given receptor**

Geographic Distribution of Estimated Anthropogenic Mercury Emissions in the U.S. (1999) and Canada (2000)



Geographic Distribution of Largest Anthropogenic Mercury Emissions Sources in the U.S. (1999) and Canada (2000)





Total Hg emissions (kg/year)

- 0 - 100
- ◊ 100 - 300
- ◻ 300 - 500
- △ 500 - 700
- 700 - 1000
- 1000 - 1300
- ◻ 1300 - 7000

- Coal-Fired Electricity Generation
- Waste Incineration
- Metallurgical
- Manufacturing
- Other Fuel Combustion

6. Getting the source-apportionment information we all want is difficult

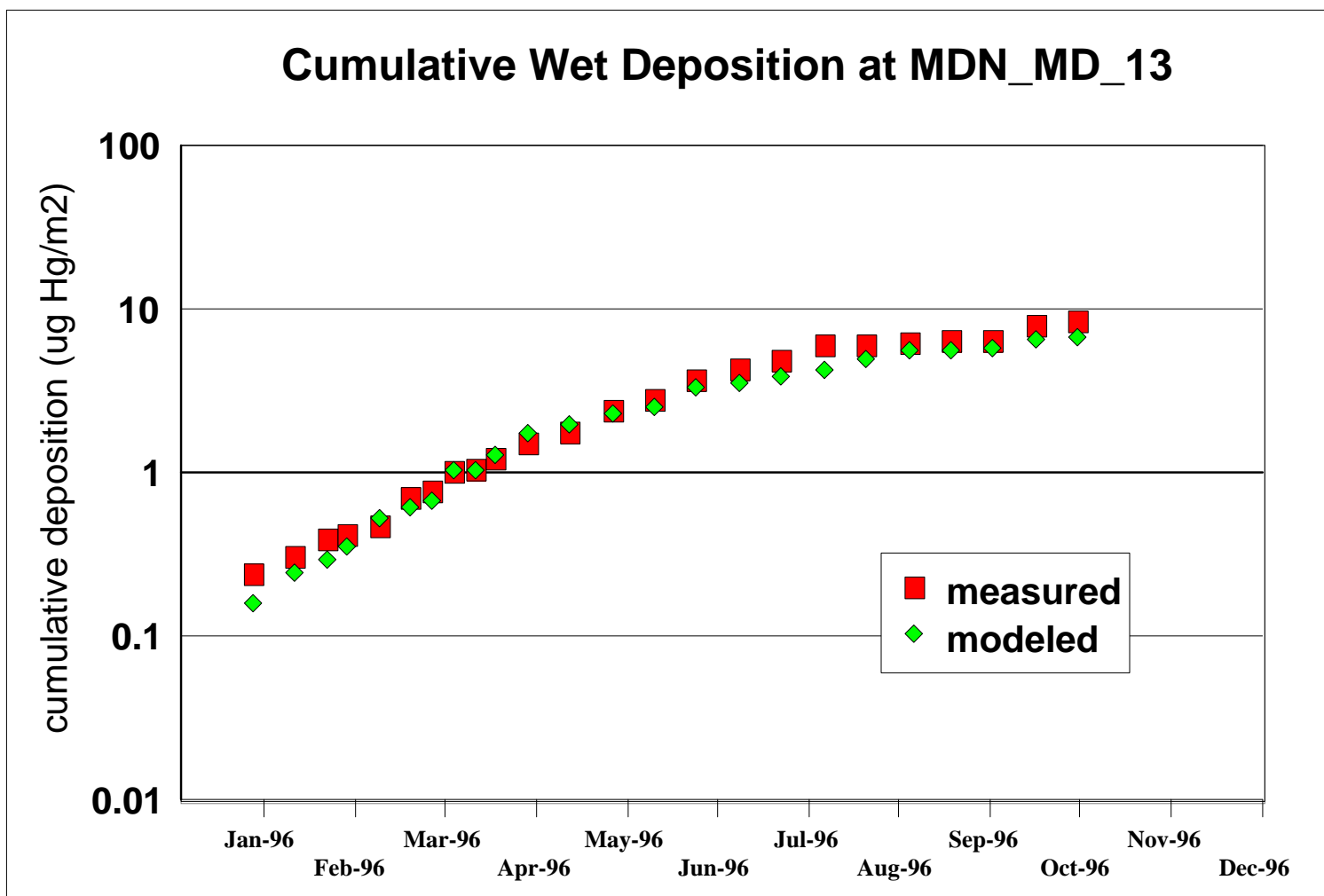
- ❑ With measurements alone, generally impossible**
- ❑ Coupling measurements with back-trajectory analyses yields only a little information**
- ❑ Comprehensive fate and transport modeling – “forward” from emissions to deposition – holds the promise of generating detailed source-receptor information**

7. There are a lot of uncertainties in current comprehensive fate and transport models

- ☐ atmospheric chemistry of mercury
- ☐ concentrations of key reactants
- ☐ mercury emissions (amounts & speciation profile)
- ☐ meteorological data (e.g., precipitation)

8. Nevertheless, many models seem to be performing reasonably well, i.e., are able to explain a lot of what we see

Modeled vs. Measured Wet Deposition at Mercury Deposition Network Site MD_13 during 1996



Convention on Long-Range Transboundary Air Pollution

emep

*Co-operative programme for monitoring
and evaluation of the long-range
transmission of air pollutants in Europe*

TECHNICAL REPORT
1/2003 June 2003

Intercomparison Study of Numerical Models for Long-Range Atmospheric Transport of Mercury

Stage II. Comparison of modeling results with observations
obtained during short-term measuring campaigns

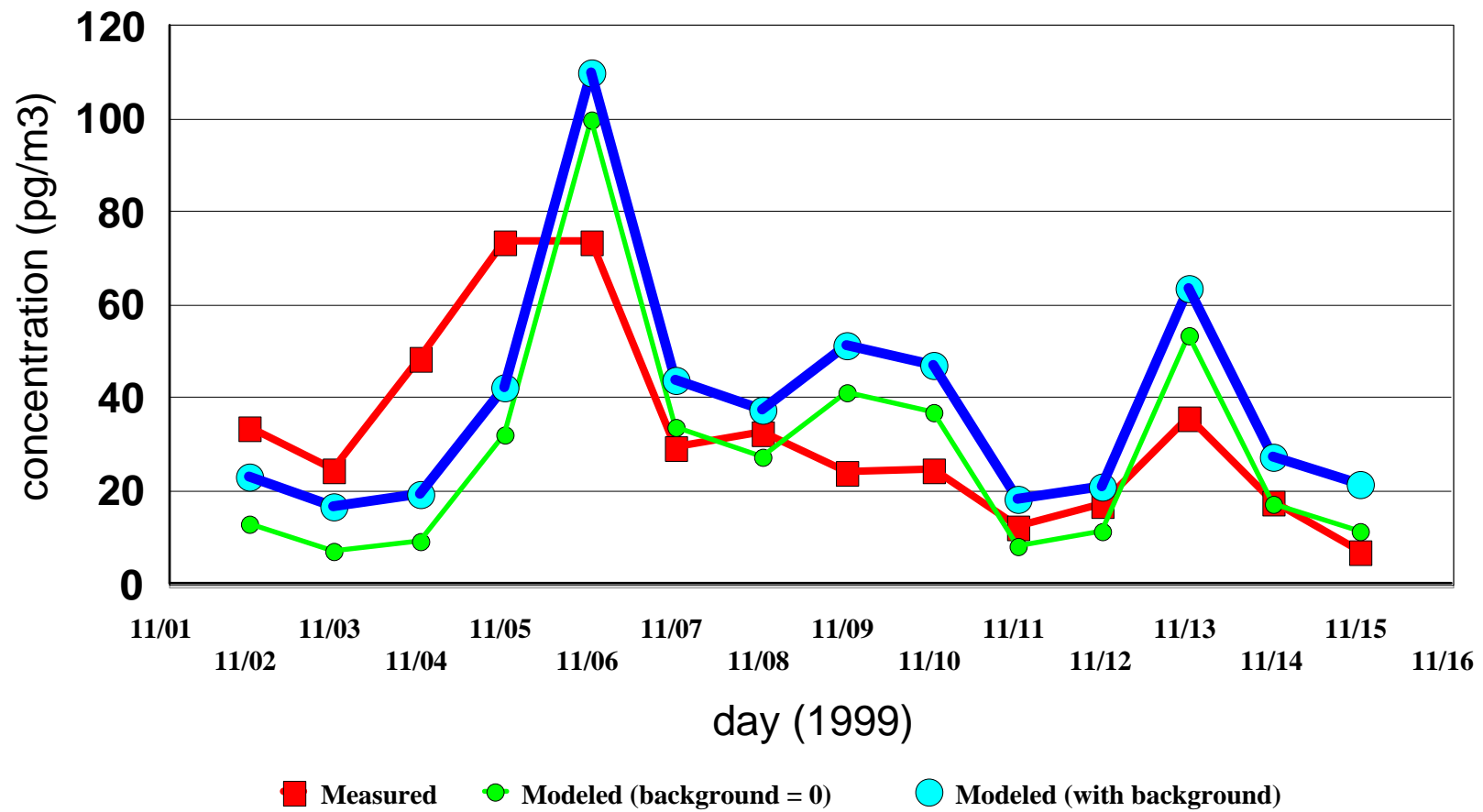
Technical Report 1/2003

A. Ryaboshapko, R. Artz,
R. Bullock, J. Christensen,
M. Cohen, A. Dastoor,
D. Davignon, R. Draxler,
R. Ebinghaus, I. Ilyin,
J. Munthe, G. Petersen,
D. Syrakov



MSC-E

Comparison of measured vs. modeled TPM Zingst



9. A model does not have to be perfect in order to be useful

- ❑ Often, most decisions just require qualitatively reasonable results**
- ❑ And realistically, most if not all data and information used in decision-making has uncertainties (e.g., public health impacts, economic impacts)**
- ❑ So, we shouldn't demand perfection of models**

*10. To get the answers
we need, we need
to use both
monitoring and
modeling --
together*

**Monitoring
needed to
develop
models and to
evaluate their
accuracy**

**Modeling
needed to help
interpret
measurements
and estimate
source-
receptor
relationships**

11. MDN is GREAT!...but there are some big gaps in atmospheric monitoring – making it very difficult to evaluate and improve models

- ☐ We desperately need national MDN-like network to measure ambient air concentrations of Hg₀, Hg(p), and RGM, *with readily available data*
- ☐ What is RGM? What is Hg(p)?
- ☐ Both “background/regional” *and* near-source measurements needed...
- ☐ Measurements at different heights in the atmosphere

Dry Deposition?

- ❑ *Dry deposition is important, and difficult – if not impossible – to measure reliably with current techniques...*
- ❑ *Essentially all dry deposition estimates made currently are made by applying models*
- ❑ *National ambient network of speciated ambient measurements will help to evaluate and improve models of dry deposition*

Source-Appportionment
where does the *mercury* in
***mercury deposition* come from?**

Source-apportionment answers depend on

❑ *where you are, and*

❑ *when you are*

*(and the effects of deposition
will be different in each ecosystem)*

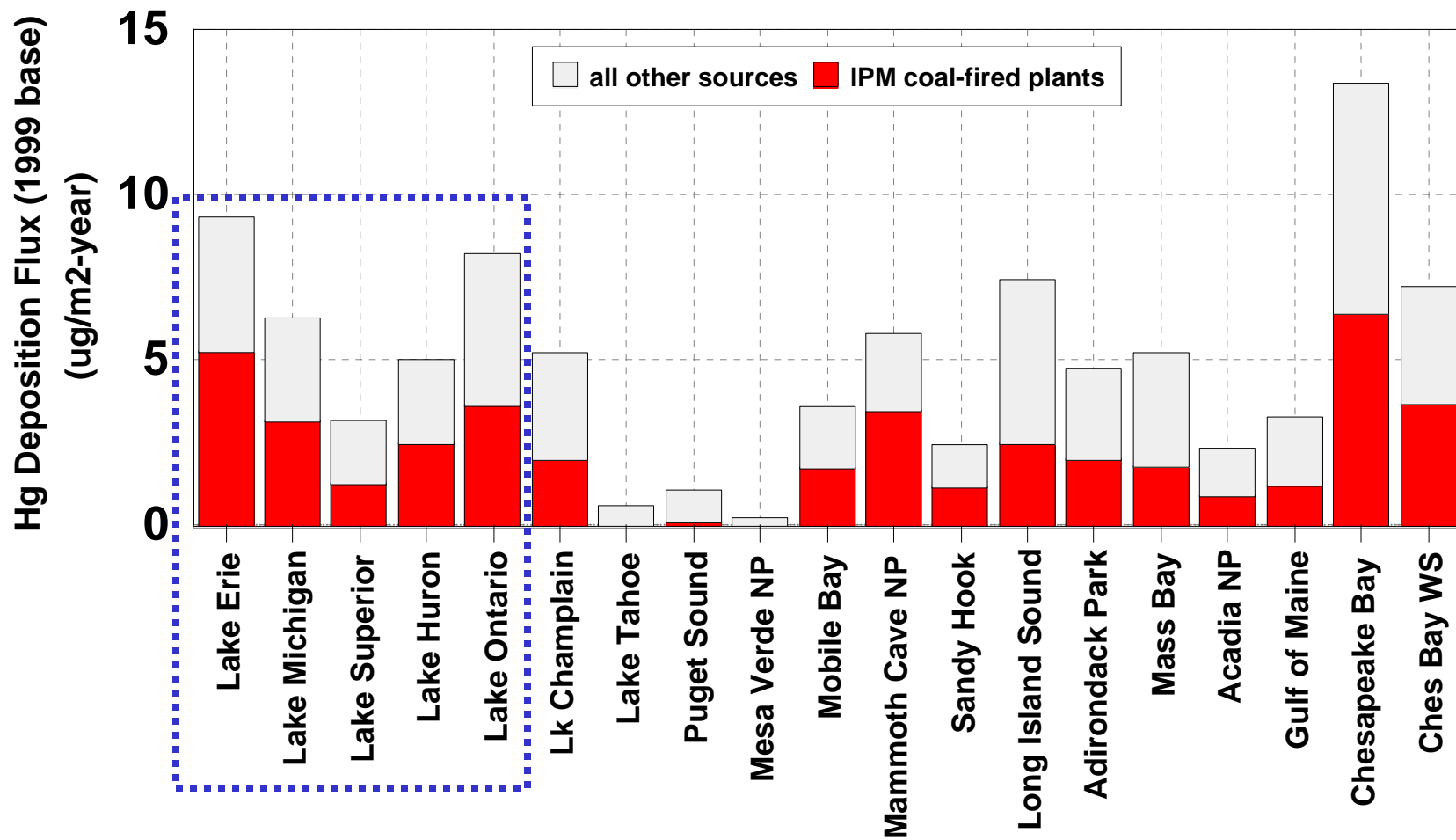
☐ **For areas *without large emissions sources***

- ☐ the deposition may be relatively low,
- ☐ but what deposition there is may largely come from natural and global sources

☐ **For areas *with large emissions sources***

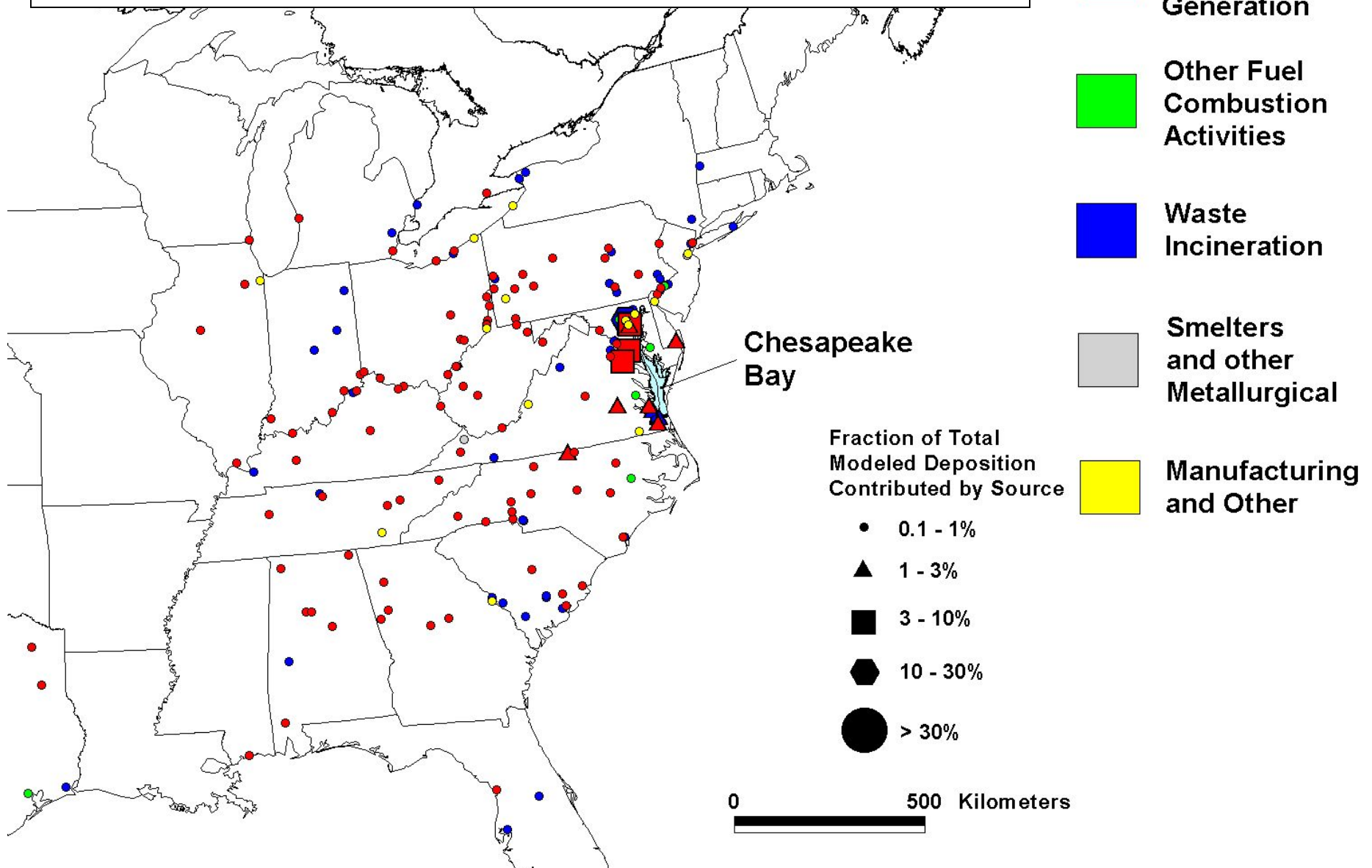
- ☐ the deposition will be higher
- ☐ and be more strongly influenced by these large emissions sources...

**Mercury deposition at selected receptors arising from 1999 base-case emissions from anthropogenic sources in the United States and Canada
(IPM coal fired plants are large coal-fired plants in the U.S. only)**

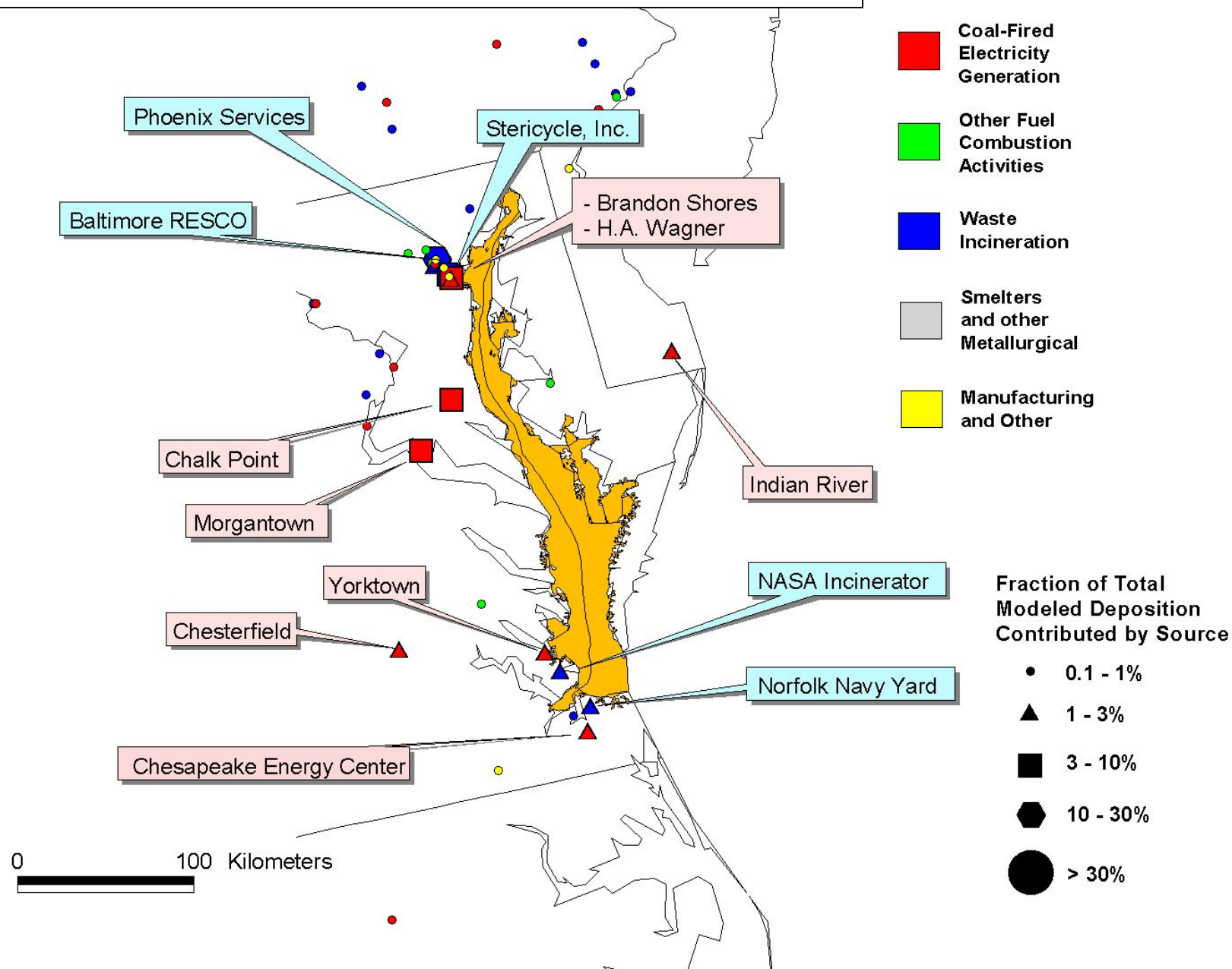


Example of modeling results: Chesapeake Bay

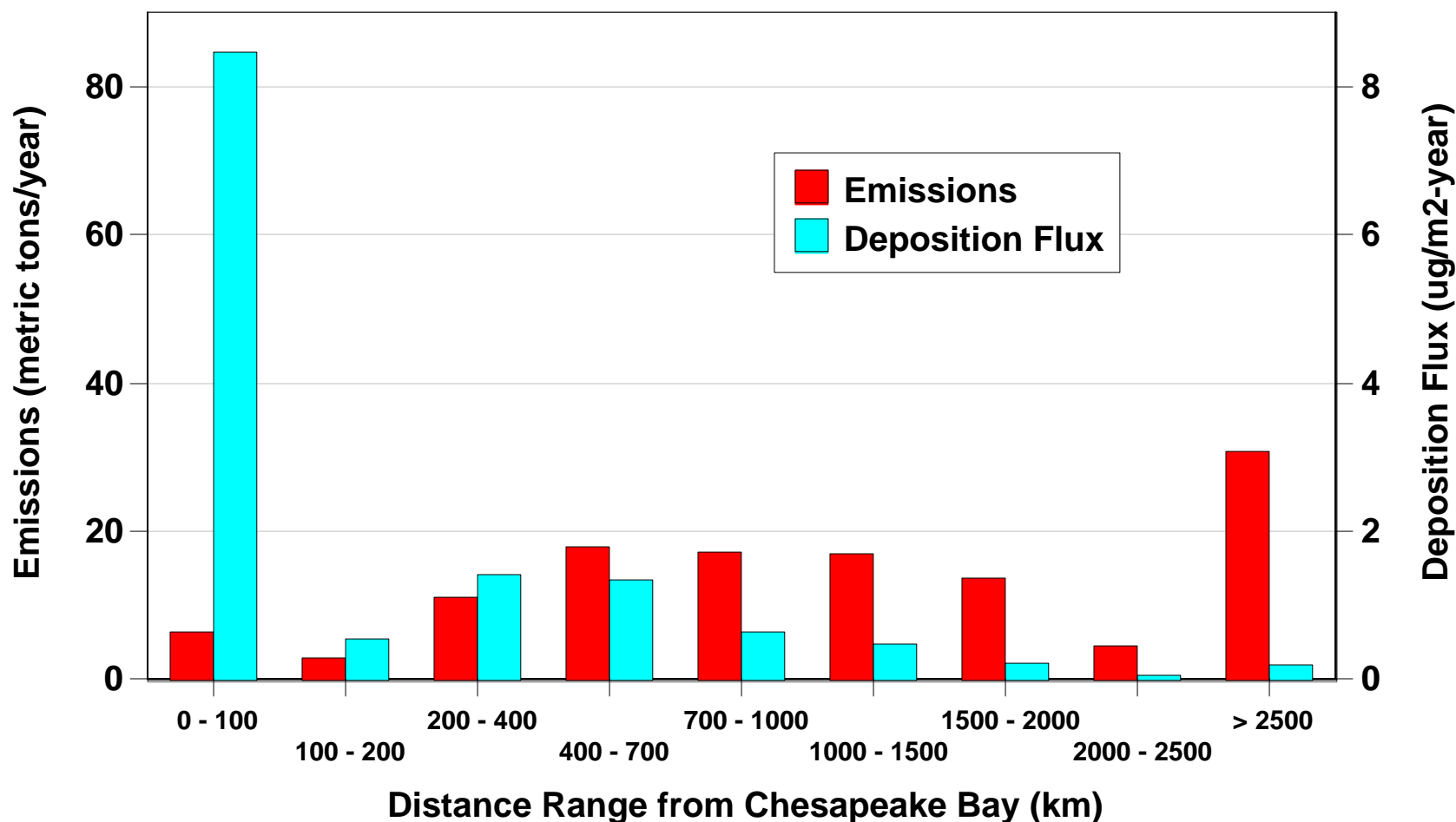
Largest Regional Individual Sources Contributing to 1999 Mercury Deposition Directly to the Chesapeake Bay



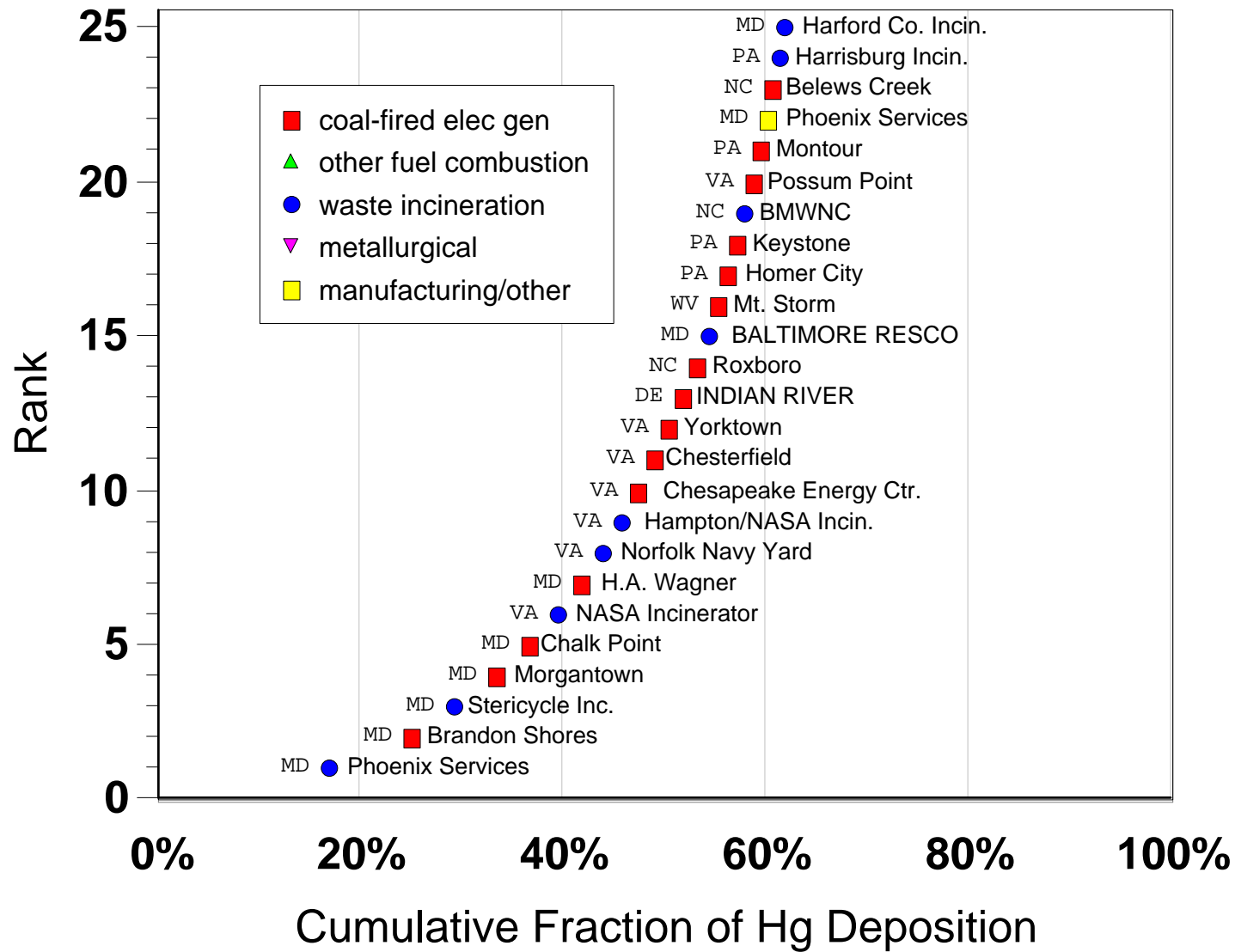
Largest Local Individual Sources Contributing to 1999 Mercury Deposition Directly to the Chesapeake Bay



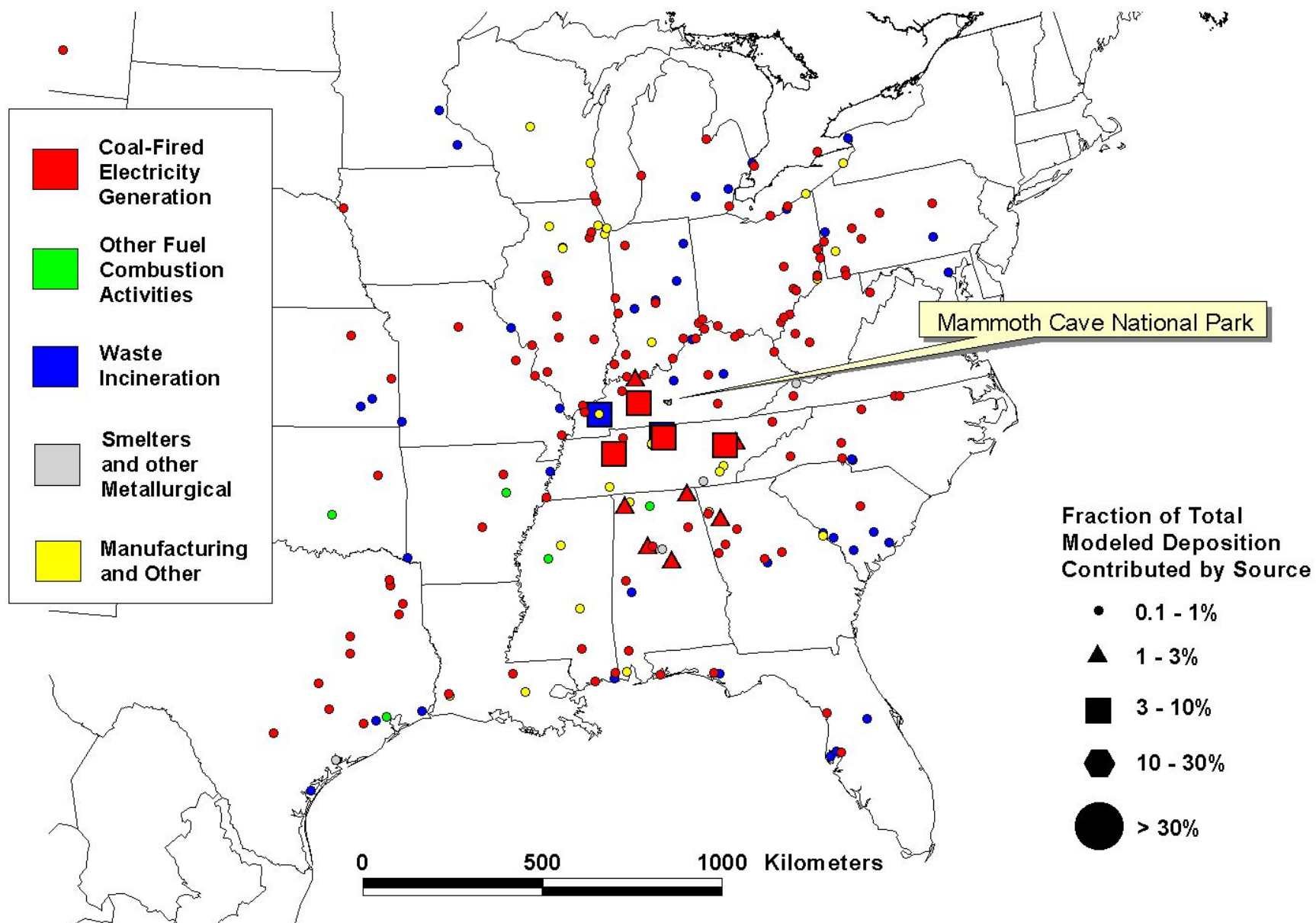
Emissions and Direct Deposition Contributions from Different Distance Ranges Away From the Chesapeake Bay

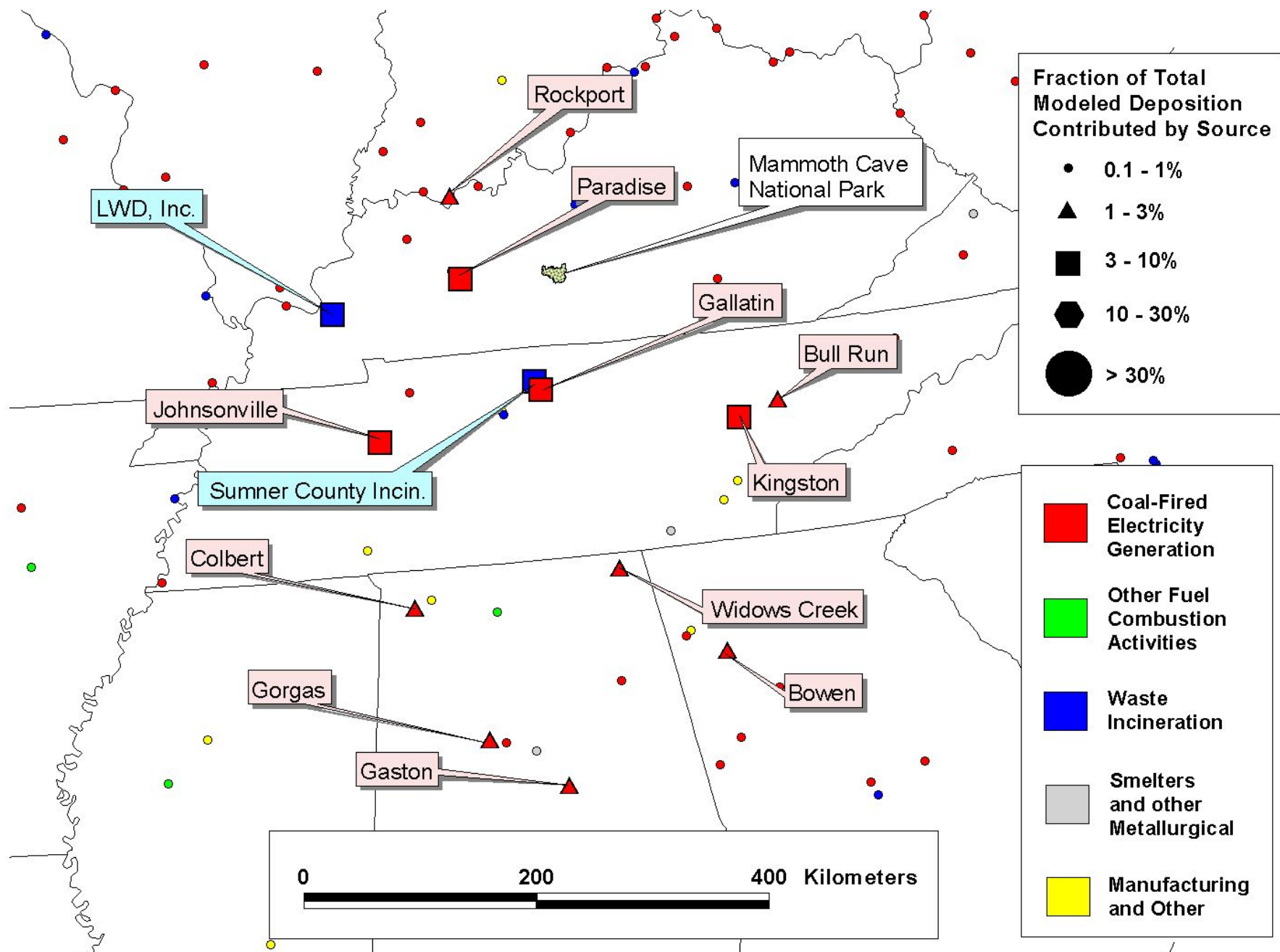


Top 25 Contributors to 1999 Hg Deposition Directly to the Chesapeake Bay

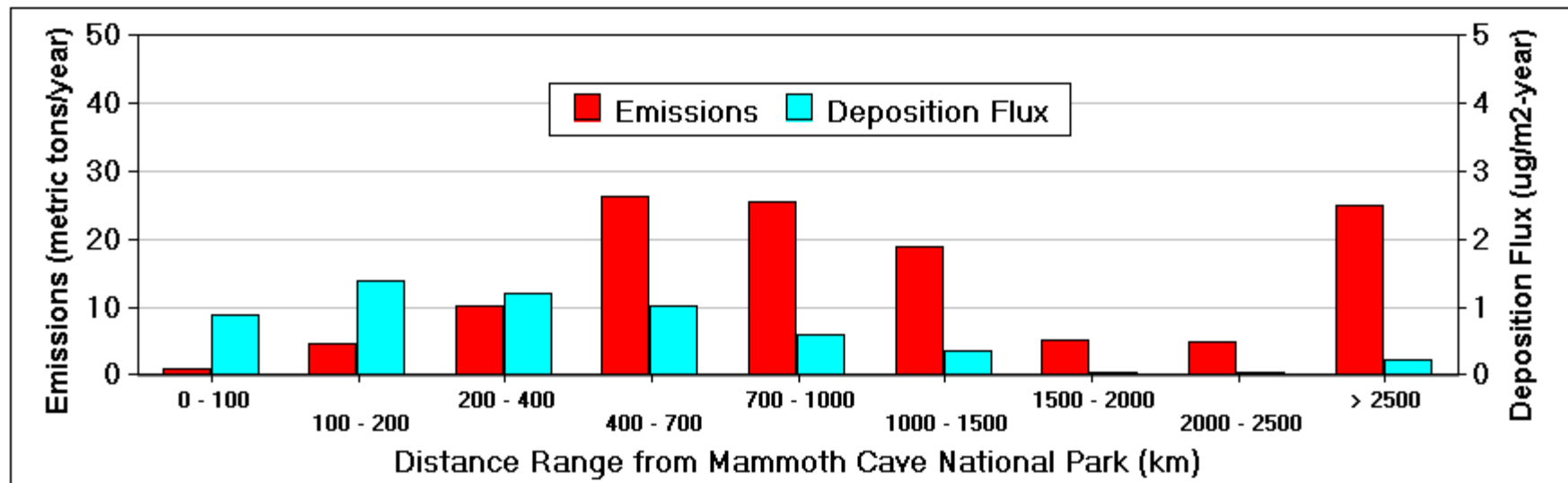


**Example of
modeling results:
Mammoth Cave
National Park**

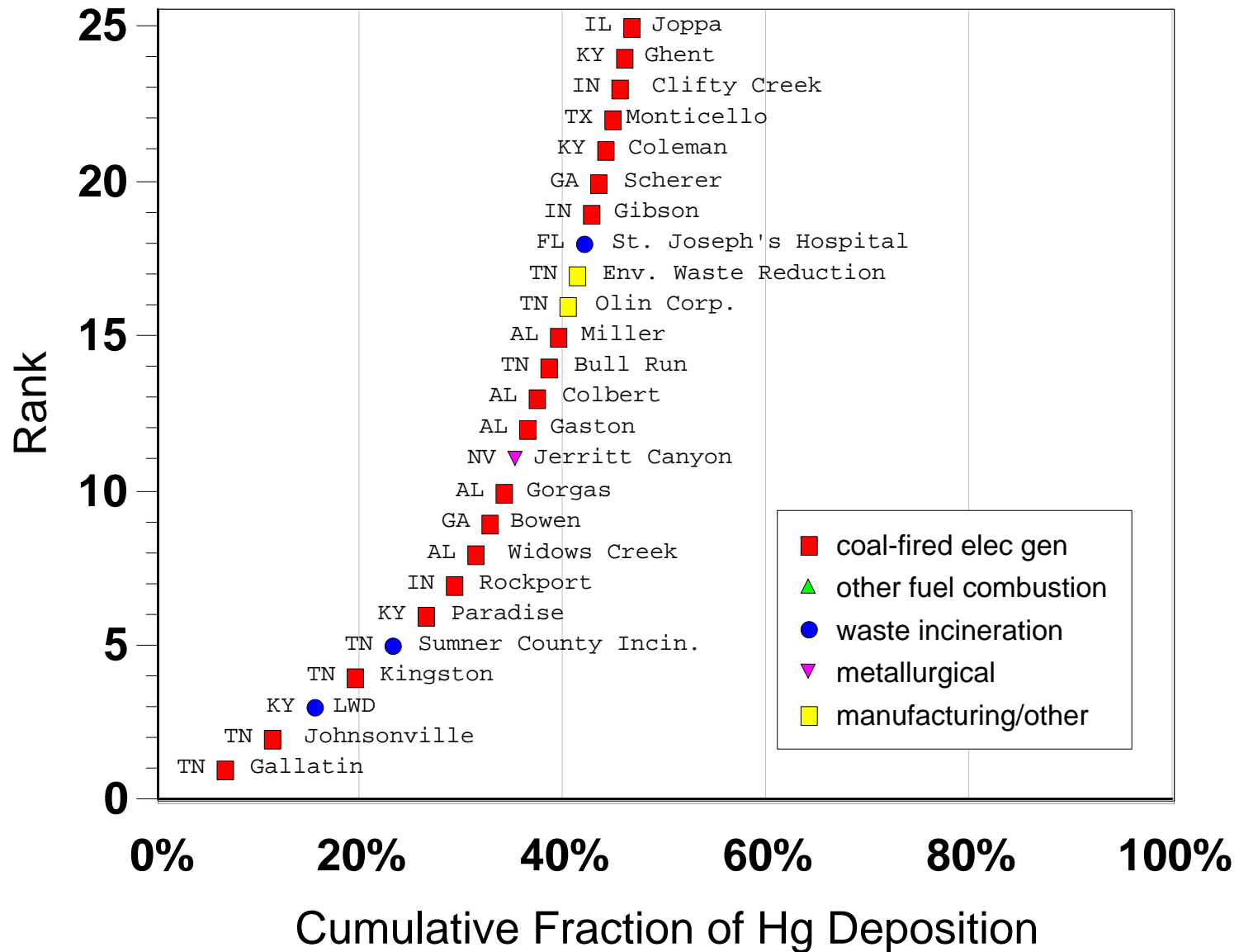











Emissions and Deposition arising from different distance ranges away from Mammoth Cave National Park



Top 25 Contributors to Hg Deposition to Mammoth Cave National Park



Conclusions

-  **Source-attribution information is important**
-  **Impacts are episodic & depend on form of mercury emitted**
-  **Modeling needed to get source-attribution information**
-  **(more!) Monitoring for model evaluation & refinement**
-  **Models don't have to be perfect to give useful information**
-  **Many uncertainties but useful model results are emerging**
-  **Many opportunities exist for improvements in modeling/monitoring integrated approaches to develop source-attribution information**